Magnetically-Actuated Propellant Orientation (MAPO)

Project Number: 93-18

Investigators: M. Van Dyke/EP63
J. Martin/EP63

Purpose

The Magnetically Actuated Propellant Orientation (MAPO) project was initiated to evaluate through experimental testing the feasibility and practicality of using magnets to manipulate magnetic fluids during periods of microgravity. The fluid of specific interest is liquid oxygen (lox) which is paramagnetic (i.e., it exhibits a tendency to be attracted to a magnetic field). The lox was simulated with a water-based ferromagnetic mixture for this investigation.

The primary objective of the project was to obtain experimental data which could be used in the development and verification of computational fluid dynamics (CFD) models. Positive results in correlating the experimental data to predicted fluid motion will provide a starting point for predicting the motion of lox in spacecraft environments. This modeling could ultimately be used in the design process of future propellant tankage.

Background

In a low-g environment, the acquisition and transfer of vapor-free propellant is not as straightforward as similar operations on the ground. The indeterminate location (figure 1) of the bulk liquid within the propellant tank complicates the design of engine feed and transfer systems. These rely on proper liquid orientation and an understanding of fluid motion in response to disturbances and imposed accelerations. The methods utilized to solve these problems in the past include the use of screen channel and vane propellant management devices (PMD's) and thruster settling burns. These techniques, however, do have drawbacks. PMD's are typically massive and bulky, and their reliability with cryogens is highly questionable. Moreover, settling burns complicate fight operations and require additional hardware and propellant.

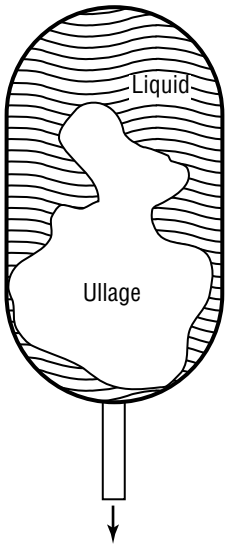

FIGURE 1.—Low gravity coast.

An alternative to these traditional approaches of propellant control is to exploit the magnetic property of fluids such as lox by using magnets to control its position. Since lox is strongly attached to regions of higher flux densities in a magnetic field, it will tend to accumulate around a magnet (figure 2) and could be used for fill, drain, and settling operations.

Liquid hydrogen (LH_2) is also influenced by magnetic fields but in a diamagnetic or "repulsive" manner (the opposite of lox). This behavior could be the subject of future work; however, the scope of the MAPO program was restricted to the attractive paramagnetic phenomena.

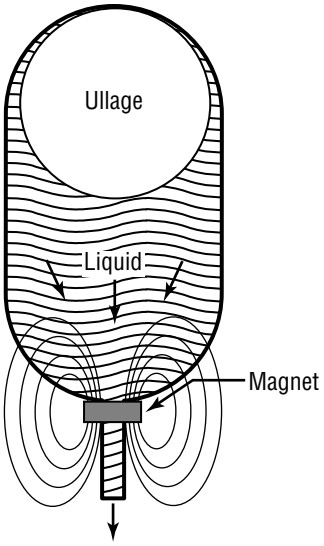

FIGURE 2.—Low gravity coast with magnet.

Approach

Experimental test hardware was built at the Marshall Center and flown aboard the NASA reduced-gravity workshop, a KC–135A aircraft operated by the Johnson Space Center (JSC). The low-gravity environment obtained aboard this aircraft was necessary to examine the fluid/magnetic field interaction. In an effort to broaden the range of scaling conditions and physical properties, the water-based ferrofluid was tested at several different mixture strengths and several different initial fluid orientations. The experimental data was recorded in the form of video tape of the fluid motion and accelerometer readings of the test package environment.

Accomplishments

A KC–135 flight test of the MAPO hardware was made in January 1997. Fluid motion/accelerometer data were collected for several fluid mixture strengths with various initial fluid positions.

Detailed measurements where taken of the test fluid properties (surface tension, contact angle and magnetization) and the magnetic field for the rare Earth magnet.

An Internet website for MAPO was created and is available from the Propulsion Laboratory's home page or directly at: http://photo3.msfc.nasa.gov/EP25/mapo/index.html. The website is being continually updated and contains information such as hardware and flight descriptions/images/movies along with test data.

Planned Future Work

- Complete the review and reduction of test data taken from the January flight and make it available to the MAPO website.

- Complete the current in-house effort to develop a computational fluid model which can simulate the magnetic effects under investigation. Use the KC–135 test data to anchor this model.

- Potential for flying a magnetically controlled lox experiment on the KC–135 as a joint effort with JSC and Oceaneering Space Systems (OSS). JSC will provide funding to OSS for hardware and MSFC will provide the MAPO data acquisition hardware and KC–135 flight credit. This data will further anchor the computational fluid dynamics model.

Funding Summary ($k)

All program funding has been spent; no additional funding is required.

FY93	FY94	FY95	Total
72	35	4	111

Status of Investigation

Project approved—October 1, 1992

It is requested that the MAPO CDDF be continued into FY98 with an estimated projected completion date of March 1998. No additional funding is required to complete this project.